

ER-8082 REV 2-77



E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE

EMPLOYEE RELATIONS DEPARTMENT

cc: H. J. Adam w/attachment
J. R. Martin w/attachment
A. C. Haven, Int'l Dept. w/attachment

August 24, 1978

D. J. KERR
DU PONT (U.K.) LTD.
HEMEL HEMPSTEAD

DETERMINATION OF ASBESTOS IN TALC

Ref: Letter of L. Appleby to D. J. Kerr July 11, 1978

You recently requested comments on the adequacy of determining asbestos in talc by the current optical microscope method and the advisability of converting to use of a scanning electron microscope or an x-ray diffraction apparatus for this analysis. We have studied this problem and our conclusion is that it would be premature at this time to change to another method.

The information provided by the Barrot article on the deficiencies of the phase contrast microscope method is not new. In May, 1977 the Analytical Chemistry Division of the (U.S.) National Bureau of Standards listed a number of objections to the phase contrast microscopic technique in a project carried out for the Occupational Safety and Health Administration (excerpt attached). Some talc producers have also questioned the method. The procedure is not very precise (+ 70% for 95% confidence limits), it is subjective in nature and its ability to differentiate between asbestos and other fibers has been questioned.

However, the current U.S. Government Regulations still require the optical method of analysis for workplace air sampling. The National Institute for Occupational Safety and Health issued a "Revised Recommended Asbestos Standard" in December, 1976. This publication surveyed the state of the art (scanning electron microscope, x-ray, differential thermal analysis, etc.) and concluded, "... phase contrast microscopy is the only generally available and practical analytical technique at the present time ..."

DUP 1110951

THERE'S A WORLD OF THINGS WE ARE DOING SOMETHING ABOUT

DU 054945

D. J. Kerr
August 24, 1978
Page Two

"Application of [electron microscope] techniques to routine samples is not practical because of extremely high analysis costs (\$200 - \$400/sample), long analysis times and limited equipment availability."

We also call your attention to the conclusions reached by the U.K. Health and Safety Commission's Advisory Committee on Asbestos (article enclosed). They concluded that the current optical method should be retained because alternative techniques are not yet developed to the point at which they could be put into reliable everyday use.

In addition, the new techniques have not been correlated to the data generated to date on exposure and disease development or TLVs. This commission did call for an expansion of research to develop new and existing techniques for monitoring asbestos.

There is no work underway at present in Du Pont U.S.A. to develop a better method for determining asbestos in minerals. However, we are maintaining a surveillance of the developments in the field and we will advise you if a change in procedures is recommended.

SAFETY AND FIRE PROTECTION DIVISION

W. C. Haaf per JRM
W. C. Haaf, Occupational Health
Engineer
Engineering Section

JRM:pch

Attachments - 2

DUP 1110952

DU 054946

**A REPORT ON THE FIBER CONTENT
OF EIGHTY INDUSTRIAL TALC
SAMPLES OBTAINED FROM, AND
USING THE PROCEDURES OF, THE
OCCUPATIONAL SAFETY AND
HEALTH ADMINISTRATION**

Prepared for
Occupational Safety and Health Administration
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May 1977



U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

DUP 1110953

DU 054947

I. INTRODUCTION

A. Purpose of Study

This report has been prepared in response to a request received by Dr. John D. Hoffman, Director of the Institute for Materials Research of the National Bureau of Standards (NBS), in a letter dated September 1, 1976, from Dr. Morton Corn, Assistant Secretary of Labor, Occupational Safety and Health Administration (OSHA). In that letter, Dr. Corn stated that analysis of talc samples for their asbestos content was being performed by OSHA and the National Institute of Occupational Safety and Health (NIOSH) but that the methodology was being challenged by some of those regulated by OSHA.

Dr. Corn indicated that his request to NBS was composed of two tasks:

- (1) to resolve the variability in the definition of asbestos fibers in talc, and
- (2) to determine the asbestos content of some 80 talc samples to be provided by OSHA.

Copies of the letter containing this request and the subsequent correspondence between Drs. Hoffman and Corn which provide further background information, are included in this report as Appendix I.

It was agreed by both parties that the first of these tasks, *i.e.*, resolving the variability of the definition of asbestos fibers, would be a complex, long-term program which would require input from a number of sources both in the private and public sectors. In view of this, it was agreed that the more limited task, that of determining the asbestos content of the OSHA talc samples, would be addressed by NBS first. As Dr. Corn pointed out in his letter of October 8, 1976, this was recognized not to be a research task but would involve an analysis performed according to the procedures given in 29 CFR 1910.1001.

29 CFR 1910.1001 [39 FR 23502, June 27, 1974, as amended in 41 FR 11505, March 19, 1976] deals exclusively with airborne asbestos and does not describe procedures for, nor make any reference to asbestos in talc. It does, however, include the following two paragraphs which are pertinent to the work discussed in this report:

"(a) *Definitions.* For the purpose of this section, (1) 'Asbestos' includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) 'Asbestos fibers' means asbestos fibers longer than 5 micrometers.

"(e) *Method of measurement.* All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400-450 X (magnification) (4 millimeter objective) with phase contrast illumination."

These regulations do not, however, describe a measurement *procedure* but rather prescribe a *method* of measurement (*viz.*, phase contrast microscopy). A *procedure* contains a detailed listing of the sampling of the material, the specific experimental steps to be performed during an analysis, and, often, descriptions of the mathematical calculations to be performed and of the format for reporting results and their associated errors. A *method* of measurement is defined by a very general statement of the type of measurement to be made, from which a specific *procedure* is developed.

Since 29 CFR 1910.1001 stipulates only that the method of phase contrast microscopy is to be used for the determination of asbestos, NBS requested a detailed procedure from OSHA. In response, NBS was provided with a copy of the OSHA document "Asbestos Fiber in Air" - Method No. P&CAM 239,

issued March 30, 1976. NBS was also informed that the determination of asbestos, including asbestos in talc, was performed at the OSHA Salt Lake City, Utah, laboratory (OSHA-SLC), using P&CAM 239. Method No. P&CAM 239, however, deals only with the determination of asbestos in air using phase contrast microscopy to examine membrane filters. Since the determination of asbestos in talc is not described in the document, NBS was told to contact Mr. Willard C. Dixon at OSHA-SLC to obtain an exact description of the procedure used on talc samples.

To become familiar with the asbestos in talc procedure, an NBS scientist then visited the OSHA-SLC laboratory and obtained verbal and written descriptions of the procedure used. He spent approximately one and one-half days at the laboratory observing the procedures and techniques used and discussing them with the OSHA employees. At the conclusion of the visit he wrote a detailed report of what he had observed. This report was submitted to Mr. Dixon for comment. A copy of the report is included as Appendix II to this document. The portions of the report that are enclosed in boxes are the comments added by OSHA-SLC personnel.

NBS scientists also discussed the analysis of talc with a number of other persons. Those contacted are listed in Appendix III to this report.

Prior to commencing the actual analysis of the 80 talc samples, we were assured by OSHA personnel that 29 CFR 1910.1001, P&CAM 239 and the annotated NBS trip report were the only documents appropriate for documenting the analytical procedure to be employed, and that the process followed by NBS in developing the detailed procedure was proper.

The detailed procedure followed at NBS is given in Section II of this report; however, a brief description of the procedure, and some comments, are given below:

Phase contrast microscopy, with a mounting medium having an index of refraction of 1.546, is used. Both fibers (a fiber being defined as having a minimum length of 5 μm , a maximum diameter of 5 μm , and a minimum length to diameter ratio of 3:1) and other particles are counted.

Early in the study we determined that the identification of "asbestos" with the procedure used was extremely difficult for the following reasons:

(1) Since phase contrast microscopy is only a contrast mechanism, it does not indicate the *degree* of difference between the refractive index of the liquid and a particle or fiber. For example, if a specimen is mounted in a liquid which matches a refractive index of chrysotile, then the particles and fibers counted would include all fibers which do not have that particular refractive index, *e.g.*, talc, anthophyllite, wollastonite, fiber glass, etc. The same would be true for any other liquid used.

(2) Most mineral species have three refractive indices; therefore, any mineral fiber not lying in the correct orientation for the selected liquid will not match and would be visible and would be counted.

(3) The amphiboles are end members in solid solution. As a result there may be a large range of refractive indices from one end member to another. One example of such a series would be the tremolite-actinolite solid solution.

(4) In addition, the most common methods of talc formation are the hydrothermal alteration of ultrabasic rocks such as serpentine and tremolite and the thermal metamorphism of siliceous dolomites. Therefore, during the formation of talc in contact with other minerals, there may be extensive interconversions between talc and the minerals serpentine, tremolite and anthophyllite. These interconversions may give rise to single particles which have a combination of the talc, anthophyllite, and serpentine mineral phases.*

(5) There are many materials which may be present in talc which have overlapping refractive indices, *e.g.*,

<u>Mineral</u>	<u>Refractive Index</u>
Wollastonite	1.63
Tremolite	1.599 - 1.637
Quartz	1.55
Talc	1.539 - 1.589
Chrysotile	1.493 - 1.567

(6) Even if the refractive indices were known, positive identification of minerals could not be made since there may be interferences from other materials.

* Deer, W. A., Howie, R. A., and Zausman, J., *Rock Forming Minerals*, Vol. 3, Longmans, Green and Co. Ltd, London, England (1967) pp. 126-128.

No easy solution to asbestos monitoring

An expansion of research to develop new and existing techniques for monitoring asbestos is called for in the second report of the Health and Safety Commission's Advisory Committee on Asbestos (HMSO, £1). Airborne asbestos levels in factories are now measured by drawing air samples through a membrane filter and counting the number of fibres trapped by phase contrast optical microscopy. The technique is simple, cheap and relatively quick. Unfortunately, it also has faults. Interlaboratory studies have shown errors as large as 50 per cent. More important, the technique counts only those fibres visible under an optical microscope—those down to about 1 micrometre in diameter.

These, says the report, "may represent only a small proportion of the number of airborne fibres". Curiously, however, the report does not spell out the significance of this limitation—that the current

sampling technique misses precisely those fibres which the current medical consensus believes to be most important in causing cancer.

Despite these faults, the report recommends that the current technique should be retained. One reason for this "conservatism" is that alternative techniques are not yet developed to the point at which they could be put into reliable everyday use. Other techniques were found, the dust measurements accumulated so far as part of crucial research projects attempting to correlate exposure to the development of disease might be invalidated, because the new techniques are not necessarily compatible.

The Health and Safety Executive has also already acted on another recommendation of the advisory committee—to measure the size distribution of fibres in a range of industrial samples. The point of this exercise is to assess whether

the proportion of minute fibres the light microscope misses (which are seen by electron microscopy) are constantly related to the number of "visible" fibres. If it were, measurements by electron microscopy could be relatively easily converted to equivalents of phase contrast measurements. Unfortunately, evidence so far indicates the opposite.

● The first report of the advisory committee, published simultaneously with the second, recommends a ban on sprayed asbestos and on asbestos applied solely for acoustic or thermal insulation (but not on products such as asbestos cement boards which have other functions). The advisory committee also proposes a licensing system to control "cowboy" companies installing or stripping asbestos insulation. It does not recommend that safety representatives in the insulation industry be given greater powers than those in other industries, as the General and Municipal Workers Union had demanded.

DUP 1110959

DU 054953

TO: J. R. Martin
ERD - S&FP

8/22/78

FROM: A. C. HAVEN
Ext. 7098 Environmental & Safety Coordinator
4031 Du Pont Bldg. International Department

DUP 1110960

DU 054954



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INTERNATIONAL DEPARTMENT
CABLE ADDRESS 'FORELPONT' WILMDEL

cc: B. C. McKusick - Haskell Lab.
C. J. Peters - F. & F.

August 16, 1978

H. G. DRINKWATER
DISA - GENEVA

ANALYSIS OF TALC FOR ASBESTOS

Ref. Your July 20 letter

Enclosed are:

1) OSHA Standard for Asbestos, which describes very briefly the analytical technique to be used in monitoring for asbestos in the workplace atmosphere. Note that an optical microscope is used.

2) Excerpts from a NIOSH criteria document entitled "Revised Recommended Asbestos Standard", which recommends the use of an electron microscope, particularly a transmission electron microscope equipped with electron diffraction facilities.

As I mentioned on the phone, F. & F. are using the optical microscope approach, following the OSHA procedure and thus in compliance with the U.S. law. As you know, NIOSH often makes recommendations which are quite conservative relative to what the OSHA people select as a standard, for example, carbon disulfide and dioxane exposure levels. Thus we feel comfortable at present with the optical microscope method. I therefore recommend you advise Maydown to continue for the present to use this analysis (with another firm if Kelsey Labs. will not oblige), or to send the samples to Marshall Lab, F. & F. if they are unable to get this work done in the U.K.

By copy of this letter I am asking Haskell Lab to consider whether Du Pont for routine control purposes should switch to the electron microscope method of analysis, as recommended by NIOSH and the Barrot reference.

A. C. HAVEN
ENVIRONMENTAL & SAFETY COORDINATOR

ACH:ecd
Enclosures

DUP 1110961

DU 054955

IV. SAMPLING METHODS AND ENVIRONMENTAL DATA

Review of Sampling and Analysis Techniques for Asbestos

A variety of sampling and analysis techniques have been used to identify asbestos fibers and determine their concentrations in air, water, mineral samples, and biologic tissue. These include optical and electron microscopy, x-ray diffraction, and differential thermal analysis. Asbestos fiber identification and quantitation in occupational and environmental air samples is difficult for a variety of reasons:

1) Asbestos fibers are generally present in low mass quantities even though fiber number concentrations may be high.

2) Many instrumental analytical techniques cannot differentiate asbestos fibers from their nonfibrous mineralogic polymorphs.

3) Many airborne asbestos fibers are generally below resolution limits of the optical microscope. These fibers may only be detected by using electron microscopic methods.

4) For identification of the various asbestos fiber types by electron microscopy, electron diffraction and microchemical analyses must be performed which require expensive instrumentation and analysis time.

(a) Electron Microscopy and Microchemical Analysis

Both transmission and scanning electron microscopy have been used for asbestos fiber identification and quantitation. In addition to morphologic observation, selected area electron diffraction and microchemical

analytical techniques may be used for fiber identification.

In addition to superior resolution capabilities, most modern transmission electron microscopes are equipped with electron diffraction facilities. Crystalline materials scatter electrons in regular patterns related to their crystal structure. The image of the scattered electrons is mainly predicted by Bragg geometry. In the transmission electron microscope, the diffraction image is formed in the back focal plane of the objective lens and is focused in the viewing screen by defocusing the intermediate lens. Visual observation of single fiber (single crystal) electron diffraction patterns may be used to differentiate chrysotile fibers from amphibole fibers (Langer et al, 1974; Timbrell 1970). Chrysotile fibers produce streaked diffraction patterns (lattice defects), with the streaks or layer lines nearly perpendicular to the fiber length. The spacing between the layer lines denotes the fiber "a" axis of approximately $5.3 \text{ \AA}$. Reflections along the layer lines are usually very streaked and Debye-Scherrer rings are common. With progressive electron beam bombardment, the diffraction pattern may change because of fiber damage. The "central core" of chrysotile fibers may also aid in fiber identification with the precaution that the central core is not always discernable and may disappear with the beam damage (Langer et al, 1974). Also, other fibrous minerals may have hollow cores.

The amphibole minerals are generally straighter in appearance than chrysotile fibers. Moreover, light and dark banding (diffraction images) may cross the fiber at right angles (Langer et al, 1974). Diffraction contrast figures have been observed on all amphibole fiber types. Selected area diffraction patterns for the amphibole asbestos minerals are all

similar in appearance; therefore, visual observation of these patterns is sufficient only to classify the fiber as being a fibrous amphibole (Langer et al, 1974; Cook et al, 1974). Amphibole electron diffraction patterns show layers and sometimes streaks perpendicular to the fiber length with the spacing between the layer lines or streaks representing the fiber "c" axis (Langer et al, 1974) of approximately $5.3 \text{ \AA}$. In contrast to chrysotile, less streaking along the layer lines is observed with the spot repeat along the lines representing one of the two remaining lattice spacings ("b" or "a") depending on fiber orientation relative to the electron beam. Typically, approximately 30 seconds is needed to perform a selected area electron diffraction analysis on a single fiber.

In addition to visual observation of electron diffraction patterns for fiber identification, photographs can be made of the diffraction patterns and crystal "d" spacings measured from the plate and calculated using the instrument camera constant (Timbrell, 1970). Both "spot" and polycrystalline patterns may be measured. It must be borne in mind that intensities may not be the same as those observed for x-ray powder patterns and additional reflections may be present.

Electron beam microchemical analytical techniques may sometimes be used to identify asbestos fibers from other fibrous particles (Rubin and Maggiore, 1974; Ferrell et al, 1975; Langer et al, 1975; Maggiore and Rubin, 1973). The most common system presently in use is the energy dispersive x-ray detector in combination with a scanning or transmission electron microscope. Wavelength x-ray analyzers and the conventional electron microprobe have been used; however, their routine application is limited because of data acquisition times (Langer et al, 1975). On the

other hand, data acquisition times with energy dispersive analyzers are far less, ranging from 20 to 80 seconds/analysis.

Semiquantitative microchemical analysis in the electron microscope is based on the fact that a beam of high energy electrons incident on an asbestos fiber generates x-rays characteristic of the elements present in that fiber. The generated x-rays are observed by means of a detector (lithium-drifted silicon crystal) placed in the electron microscope column close to the specimen. The energy of the x-ray photon is converted to a voltage pulse which is amplified, digitized and stored in a multichannel analyzer or a minicomputer. The content of the memory is usually displayed on a CRT (Maggiore and Rubin, 1973). With the energy dispersive detector, all elements with atomic numbers of sodium or higher may be analyzed. Continuous background or brehmsstrahlung radiation is always present with the x-ray spectrum.

Each of the asbestos minerals has an x-ray spectrum which is usually characteristic enough, when combined with fiber morphology, to allow its identification (Rubin and Maggiore, 1974; Ferrell et al, 1975; Dement et al, 1975). Visual observation of the semiquantitative fiber x-ray spectra is usually sufficient for fiber identification; however, three component diagrams have been used after subtracting the continuous background from the semiquantitative x-ray spectrum (Ferrell et al, 1975). For asbestos fiber analysis, matrix corrections are rarely used. Typically, iron, magnesium, and silicon are plotted on the three component diagram and compositional boundaries for the asbestos minerals established. This technique suffers from inability to use all compositional data obtained, such as presence or absence of sodium, calcium, aluminum and manganese, which aid in identification.

With energy dispersive x-ray techniques, possession of proper elemental intensities may not be sufficient for positive identification as many fibrous minerals show similar elemental intensities. For example, chrysotile, anthophyllite, and fibrous talc, which have similar elemental compositions, may be difficult to differentiate. However, these materials may easily be distinguished by using selected area electron diffraction. In addition, unique identification of the various fibrous amphiboles usually requires both selected area diffraction and microchemical analysis. Transmission electron microscopes equipped with an energy dispersive x-ray detector are now available which allow simultaneous observation of morphology, crystal structure, and elemental composition. These microscopy systems have been used to study asbestos fibers in environmental and material samples. (Cook et al, 1974; Dement et al, 1975)

Quantitative analysis of asbestos fiber concentrations in environmental and tissue samples has been accomplished by electron microscopy. Environmental samples (water and air) are generally collected by first concentrating the sample by filtration, centrifuging, etc (Cook et al, 1974; Nicholson, 1974). The filters (Millipore) and polycarbonate filters (Nuclepore) are prepared for electron microscopic analysis by various methods. For scanning electron microscopy, Nuclepore filters, because of their smooth surface, may be directly coated with an appropriate metal (gold, etc) and analyzed (Porter and Berggren, 1974). Millipore filters have a rough surface texture and are not generally suitable for direct coating for scanning electron microscopy as small fibers may escape detection due to impaction below the filter surface (Nicholson, 1974).

For transmission electron microscopy, the filter substrate must be removed and the particles mounted on suitable electron microscopy grids. A wide variety of mounting techniques have been used. The two most commonly used methods are the Jaffe Wick and condensation washing techniques. The techniques offer simplicity in addition to maintaining the original particle size distribution of the sample. Different investigators have reported particle losses up to 60% with Millipore filters while using the condensation washing method with rapid filter dissolution, whereas losses with the Jaffe Wick method have been reported to be considerably less (>10%) (Beaman and File, 1975). Lesser particle loss has been observed with the condensation washing method when longer times for dissolution of the filter are used. Ortiz and Loom (1974) reported that a modification of the Jaffe Wick method, whereby the filter is first coated with silicon monoxide and carbon by vacuum evaporation prior to dissolving the Millipore filter, minimized particle loss. Several investigators have reported minimal particle loss with Nuclepore filters when the filter is first carbon-coated prior to dissolving the filter substrate (Cook et al, 1974; Maggiore and Rubin, 1973).

In addition to the so-called direct clearing/mounting techniques mentioned above, many other techniques have also been used for preparing environmental samples. Seikoff et al (1972) have used a so-called "rub-out" technique whereby the Millipore filter is ashed in a low temperature asher to remove organic or carbonaceous material. The residue is then dispersed on a microscope slide using a solution of 1% Nitrocellulose in amyl acetate. After grinding with a watch glass to liberate individual fibers, the sample is dispersed evenly between two microscope slides to

form a thin film which is transferred to standard electron microscope grids. Particle losses averaging 50% have been reported with this technique. This technique also increases the apparent number of fibers present due to breaking up of fiber bundles. Asbestos fiber levels in environmental samples and biologic tissue are usually expressed as asbestos fibers/unit volume of sample (fibers/m³, fibers/liter, fibers/g dry lung, etc). These concentrations are determined by counting fibers within calibrated areas on the electron microscope viewing screen or counting fibers from photographs. Asbestos fiber concentrations in water samples determined by laboratories using the same mounting techniques have been reported to vary by a factor of 2-3 (Cook et al, 1974). Much larger variations have been reported between laboratories using different techniques.

Asbestos mass (chrysotile) concentrations in environmental samples have also been determined using electron microscopy. This is accomplished by measuring the length and diameter (volume) of each fiber and calculating the mass using the appropriate density (Selikoff et al, 1972). The accuracy of this technique has not been studied in detail.

Electron microscopic techniques represent the "best available" methods for asbestos fiber analysis. However, application of these techniques to routine samples is not practical because of extremely high analysis costs (\$200-\$400/sample), long analysis times, and limited equipment availability.

(b) X-Ray Diffraction

X-ray powder diffractometry is one of the standard mineralogic techniques used in the analysis of solid crystalline phases. X-ray

diffraction has been widely used for identification and quantitation of asbestos fibers in bulk materials such as talc (Stanley and Norwood, 1974; Rohl and Langer, 1974) and other industrial materials (Crable and Knott, 1968; Keenan and Lynch 1970).

X-ray diffraction has also been used to study amphibole asbestos contamination of water samples (Cook et al, 1974). X-ray diffraction is generally considered more sensitive for asbestos than light microscopy, although less sensitive than electron microscopy (Rohl and Langer, 1974).

Diffraction lines and relative intensities for each of the asbestos minerals have been published and may be found in the ASTM Powder Diffraction File. Variations in asbestos fiber chemical composition, especially for the amphiboles, may result in slight peak shifts from reported x-ray diffraction data.

Quantitative determinations of asbestos fiber levels in material samples (talc, etc) require that particle size first be reduced to an average of 0.1 - 10 μ m. Preferred orientation and surface roughness must also be eliminated.

A number of techniques have been used to minimize preferred orientation effects including binder and slurry mounting methods, sifting and backloading of dry powders, and several others. To minimize preferred orientation, Rohl and Langer (1974) have developed a method for filtering an aqueous slurry through Millipore filters using a filtration adapter attached to a hypodermic syringe. Other investigators have used the backloading technique with multiple x-ray diffraction scans.

Using conventional scan rates (0.5 - 1 degree 2 theta/minute), lower limits of detection of asbestos by x-ray diffraction of 5% in bulk samples

have been reported (Crable and Knot, 1966). Automated step scanning procedures by which diagnostic reflections are slowly scanned and integrated counts recorded have been reported to significantly reduce detectable limits. Rohl and Langer (1974) have detected anthophyllite at 2.0%, chrysotile at 0.25%, and tremolite at 0.10% by weight in a talc matrix using external dilution standards for calibration. Similar lower detectable levels have been reported by Stanley and Norwood (1974).

Application of x-ray diffraction for routine asbestos fiber analysis of environmental samples has been limited. Birks et al (1975) have reported a feasible study concerning quantitative analysis of airborne asbestos. Their technique involved alignment of the asbestos fibers in an electrostatic field to enhance diffraction intensity followed by x-ray counting in a specially designed diffraction apparatus with two x-ray detectors. A lower limit of detection of 0.4 - 0.5 μ g was reported. This technique has not been applied to actual environmental samples.

Amphibole and cummingtonite-grunerite mass concentrations in water samples have been semiquantitatively determined using x-ray diffraction with step scanning (Cook et al, 1974). This technique involves filtering the water through 0.45- μ m Millipore filters followed by step scanning a major amphibole diffraction peak (110) and a peak specific to cummingtonite-grunerite (310). The integrated peak count above background is recorded and mass concentrations are determined using external dilution standards.

Proper selection of diagnostic reflections to maximize detection sensitivity and minimize interference due to other mineral phases is necessary for proper use of x-ray diffraction. It must also be recognized

that x-ray diffraction methods are not capable of differentiating between asbestos fibers and their nonfibrous mineralogic polymorphs. This fact, combined with relatively poor detection levels, suggests that alternate techniques such as electron microscopy should be combined with x-ray analysis.

(c) Differential Thermal Analysis

Differential thermal analysis has been used to determine asbestos fiber levels in talc samples (Schlez, 1974). Chrysotile (serpentine minerals) shows a dehydroxylation endotherm at approximately 650 degrees C and an exotherm at approximately 820 degrees C, associated with the formation of forsterite. These peaks may be used for quantitative analysis. Using a 140-mg sample holder with an exposed loop differential thermocouple and a 10 degree C/minute heating rate, Schlez (1974) reported that a 1% concentration of chrysotile could be detected in pharmaceutical grade talc. A dynamic helium atmosphere was maintained to sweep out gaseous mineral decomposition products and to prevent oxidative reactions.

Differential thermal analysis has not been used for environmental samples as lower limits of mass detection are extremely poor. Differential thermal analysis, like x-ray diffraction, is not capable of differentiating between asbestos fibers and their nonfibrous mineralogic polymorphs.

(d) Optical Microscopy

A number of optical microscopic techniques have been used to identify and/or quantitate asbestos fibers in environmental samples. These include petrographic and phase contrast microscopy. Petrographic microscopic techniques may be used to identify asbestos fibers greater than approximately 0.2 - 0.3 μ m in diameter. Using the polarizing microscope,

various optical crystallographic measurements such as refractive index, extinction angles, and sign of elongation may be measured and compared with data reported for standard asbestos reference samples. Typical optical data for selected asbestos minerals are shown in Table IV-1 (Julian and McCrone, 1970).

Dispersion staining with polarized light has been used to identify asbestos fibers, as reported by Julian and McCrone (1974). With this technique, the fibers are immersed in a mounting medium with a steeper dispersion curve than the fibers. A central or annular stop is used in the objective lens back focal plant to allow either the wavelength of light at which the index of the particle matches that of the mounting media, or complements to that color to reach the observer's eye. Using plane polarized light, asbestos fibers show two characteristic dispersion staining colors; one for the light vibration parallel to and the other for that perpendicular to the fiber length. The dispersion colors depend on the refractive index media in which the fibers are mounted, as shown in Table IV-2. Dispersion staining colors may change slightly depending on the geographic area from which the asbestos was mined and subsequent treatment. Fibers less than 0.5 μ m in diameter may not be identified by this technique because of difficulties in distinguishing colors.

Phase contrast optical microscopy is the technique specified for determining the Occupational Safety and Health Administration asbestos standard (US Department of Labor 1975). The method consists of collecting breathing zone samples during 15-minute to 8-hour periods on membrane filters (millipore AA). Samples are analyzed by first clearing the membrane filter to make it optically transparent, then by fiber counts at

400-500X magnification by phase contrast optical microscopy. Asbestos fibers are defined as those particles with a length greater than 5 μm and a length-to-diameter ratio of 3:1, or greater. This technique, by which only fibers longer than 5 μm are counted, is recognized as only an index of total fiber exposure and does not imply that shorter fibers do not pose a health hazard. The relative proportion of airborne fibers longer than 5 μm has been shown by Dement et al (1975) to vary from 1 to approximately 50% depending on the industrial operation and asbestos fiber type. In addition to problems of detecting short fibers, phase contrast microscopy may not be specific for asbestos fibers in industrial operation where mixed fiber types are encountered.

Despite its limitations, phase contrast microscopy represents the only technique available that can reasonably be used for routine asbestos fiber sampling and analysis. It is adaptable to personal sampling where low air volumes are sampled and analysis equipment is readily available.

Minimum detectable fiber concentrations by phase contrast microscopy depend on a number of factors such as air volume sampled, microscope field counting area, number of microscopic fields counted, and presence or absence of nonfibrous particles. Theoretical minimum detectable concentrations may be calculated assuming one fiber longer than 5 μm is observed per 100 microscopic fields (after filter background subtraction). Table IV-3 shows theoretical minimum detectable fiber concentrations as a function of sample period for a typical microscope arrangement. For a 15-minute sampling period, 0.04 fibers >5 $\mu\text{m}/\text{cc}$ may be detected; however, with an 8-hour sample, 0.001 fibers/cc can be detected. These minimum concentrations are similar to those reported by Corn and Sansone (1974).

These authors reported that 0.01 fibers/cc could be detected with a 2-hour sample period (40 microscopic fields counted).

The above calculations represent theoretical minimum detectable concentrations, not considering the many factors affecting precision and accuracy of the technique. There are many sources of variability in the laboratory analysis technique. The major sources of variability are as follows:

- 1) Variability of fiber distribution across the filter surface.
- 2) Variability of fiber distribution on a given filter wedge being analyzed.
- 3) Variability due to differences between microscopes.
- 4) Variability due to differences between individual counters.
- 5) Variability in laboratories.

Leidel and Busch (1974) found that the fiber distribution on a given filter section could best be described by the Poisson-distribution. However, Conway and Holland (1973) found that the distribution of fibers on filters was not uniform and were more disperse than predicted by the Poisson distribution, so that concentrations between sections could vary by as much as 50-60%. Similar results were found by Rajhans and Bragg (1975) in Series I of their study.

If the Poisson distribution is taken to adequately describe fiber distributions on filter sections, the standard deviation of the fiber count may be estimated from the square root of the count. In order to maintain an acceptable Coefficient of Variation (CV) (below 20%), a minimum of 25 fibers must be counted. For a typical industrial asbestos sample of 2

hours (2 lpm flow), this would correspond to a concentration of 0.13 fibers/cc.

The precision of the entire sampling and analysis procedure (all sources of variability) has been estimated by Leidel et al (1975). These authors estimated the total CV to be 22%.

Comparisons of Asbestos Mass Concentrations

(ng/m³) and Fiber Number Concentrations (fibers/cc)

In order to relate ambient asbestos levels, which are generally expressed as ng/m³, to occupational exposures, which are expressed as fibers >5 μ m in length/cc, a conversion factor is needed. Attempts to formulate such a conversion have generally been unsuccessful because of exceptionally large variability. This is to be expected as ambient levels are generally determined using electron microscopy whereas phase contrast microscopy is used to measure occupational exposures. In addition, techniques used to prepare samples for electron microscope observation may cause alterations in fiber size (diameter and length) distributions.

Lynch and Ayer (1966) presented results of environmental studies in the asbestos textile industry where fiber concentrations were determined using phase contrast optical microscopy and fiber size distributions were determined using electron microscopy. The mass of chrysotile on the filter was estimated by using atomic absorption spectroscopy to determine the magnesium content of the sample and asbestos content was calculated, assuming a 25% magnesium content for chrysotile. These data are summarized in Table IV-4. Based on the magnesium analysis, the authors concluded that

Table Z-2

Material	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift	
			Concentration	Maximum duration
Benzene (Z37.4-1969)	10 p.p.m.	25 p.p.m.	50 p.p.m.	10 minutes
Beryllium and beryllium compounds (Z37.25-1970)	2 µg./M ³	5 µg./M ³	25 µg./M ³	30 minutes
Calcium lime (Z37.5-1970)	0.1 mg./M ³	3 mg./M ³		
Cadmium dust (Z37.5-1970)	0.2 mg./M ³	6.6 mg./M ³		
Carbon dioxide (Z37.3-1969)	20 p.p.m.	20 p.p.m.	100 p.p.m.	1 hr.
Carbon tetrachloride (Z37.17-1967)	10 p.p.m.	20 p.p.m.	200 p.p.m.	5 minutes in any 4 hours
Ethylene dibromide (Z37.31-1970)	30 p.p.m.	20 p.p.m.	80 p.p.m.	5 minutes
Ethylene dichloride (Z37.31-1969)	60 p.p.m.	100 p.p.m.	200 p.p.m.	5 minutes in any 3 hours
Formaldehyde (Z37.16-1967)	3 p.p.m.	5 p.p.m.	10 p.p.m.	30 minutes
Hydrogen fluoride (Z37.26-1969)	de.	de.	de.	de.
Fluoride as dust (Z37.26-1969)	2.5 mg./M ³			
Lead and its inorganic compounds (Z37.11-1960)	0.5 mg./M ³			
Methyl chloride (Z37.18-1969)	100 p.p.m.	200 p.p.m.	200 p.p.m.	5 minutes in any 3 hours
Methylene Chloride (Z37.3-1969)	600 p.p.m.	1,000 p.p.m.	2,000 p.p.m.	5 minutes in any 3 hours
Orpene (alkyl) mercury (Z37.30-1969)	0.01 mg./M ³	0.04 mg./M ³		
Styrene (Z37.15-1969)	100 p.p.m.	200 p.p.m.	600 p.p.m.	5 minutes in any 3 hours
Trichloroethylene (Z37.19-1967)	de.	de.	200 p.p.m.	5 minutes in any 2 hours
Tetrachloroethylene (Z37.22-1967)	de.	de.	de.	5 minutes in any 3 hours
Toluene (Z37.12-1967)	200 p.p.m.	300 p.p.m.	600 p.p.m.	10 minutes
Hydrogen sulfide (Z37.3-1969)	20 p.p.m.	30 p.p.m.	60 p.p.m.	10 minutes once only if the odor measurable exposure occurs
Mercury (Z37.9-1971)	1 mg./M ³			
Chromic acid and chromates (Z37.7-1971)	de.	de.		

Occupational exposures to benzene are subject to the requirements of Section 1910.1025 except as specifically exempted by Section 1910.1025(a)(2). Exposures exempted by Section 1910.1025(a)(2) are covered by this Section 1910.1000.

[Footnote to Table Z-2 added at 43 FR 5963, February 10, 1978]

Table Z-1—Mineral Dusts			Aerodynamic diameter (unit density sphere)	Percent passing micrometer
Nuisance	Mppcf*	Mg/M ³		
Silica:			2	80
Crystalline:			2.5	75
Quartz (respirable)	250 [†]	10mg/M ³ =	2.5	80
	%SiO ₂ +2	%SiO ₂ +2	5.0	25
Quartz (total dust)		30mg/M ³	5.0	0
		%SiO ₂ +2		
Cristobalite: Use 1/2 the value calculated from the count or mass formulae for quartz.				
Tridymite: Use 1/2 the value calculated from the formulae for quartz.				
Amorphous, including natural diatomaceous earth	20	80mg/M ³		
		%SiO ₂		
Silicates (less than 1% crystalline silica)				
Mica	20			
Serpentine	20			
Talc (non-asbestos form)	20*			
Talc (fibrous): Use asbestos limit				
Tremolite (see talc, fibrous)				
Portland cement	80			
Graphite (natural)	16			
Coal dust (respirable fraction, less than 6% SiO ₂)		2.4mg/M ³ or 10mg/M ³		
For more than 6% SiO ₂		%SiO ₂ +2		
Inert or Nuisance Dust:				
Respirable fraction	16	6mg/M ³		
Total dust	80	18mg/M ³		

Note: Conversion factors: mppcf x 35.2 = million particles per cubic meter = particles per c.c.
 * Millions of particles per cubic foot of air, based on impinger samplers operated by light-field technique.
 † The percentage of crystalline silica in the formula is the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.
 As determined by the membrane filter method at 430X phase contrast magnification.
 ‡ Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:
 • Containing < 1% quartz; if > 1% quartz, use quartz limit.

The measurements under this note refer to the use of an AEC instrument. If the respirable fraction of coal dust is determined with a MRE the figure corresponding to that of 2.4 Mg/M³ in the table for coal dust is 4.6 Mg/M³.

§ 1910.1001 Asbestos

(a) Definitions. For the purpose of this section, (1) "Asbestos" includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) Permissible exposure to airborne concentrations of asbestos fibers—(1) Standard effective July 7, 1972. The 8-hour time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

(2) Standard effective July 1, 1976. The 8-hour time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

(3) Ceiling concentration. No employee shall be exposed at any time to airborne concentrations of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (c) of this section.

(c) Methods of compliance—(1) Engineering methods. (i) Engineering controls. Engineering controls, such as, but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) Local exhaust ventilation. (a) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971, which is incorporated by reference herein.

(b) See § 1910.6 concerning the availability of ANSI Z9.2-1971, and the maintenance of a historic file in connection therewith. The address of the American National Standards Institute is given in § 1910.100.

(iii) Particular tools. All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with subdivision (ii) of this subparagraph.

(2) Work practices—(1) Wet methods. Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(ii) Particular products and operations. No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the limits prescribed in paragraph (b) of this section.

(iii) Spraying, demolition, or removal. Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d)(2)(iii) of this section and with special clothing in accordance with paragraph (d)(3) of this section.

(d) Personal protective equipment—

(1) Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:

(i) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(ii) In work situations in which the methods prescribed in paragraph (c) of

this section are either technically not feasible or feasible to an extent insufficient to reduce the airborne concentrations of asbestos fibers below the limits prescribed by paragraph (b) of this section; or

(iii) In emergencies.

(iv) Where both respirators and personnel rotation are allowed by subdivisions (i), (ii), or (iii) of this subparagraph, and both are practicable, personnel rotation shall be preferred and used.

(2) Where a respirator is permitted by subparagraph (1) of this paragraph, it shall be selected from among those approved by the Bureau of Mines, Department of the Interior, or the National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare, under the provisions of 30 CFR Part 11 (37 F.R. 6244, Mar. 25, 1972), and shall be used in accordance with subdivisions (i), (ii), (iii), and (iv) of this subparagraph.

(i) *Air purifying respirators.* A reusable or single use air purifying respirator, or a respirator described in subdivision (ii) or (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed no more than 10 times those limits.

(ii) *Powered air purifying respirators.* A full facepiece powered air purifying respirator, or a powered air purifying respirator, or a respirator described in subdivision (iii) of this subparagraph, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average concentrations of asbestos fibers are reasonably expected to exceed 10 times, but not 100 times, those limits.

(iii) *Type "C" supplied-air respirators, continuous flow or pressure-demand class.* A type "C" continuous flow or pressure-demand, supplied-air respirator shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 100 times those limits.

(iv) *Establishment of a respirator program.* (a) The employer shall establish a respirator program in accordance with the requirements of the American National Standards Practices for Respiratory Protection, ANSI Z88.2-1969, which is incorporated by reference herein.

b. See § 1910.6 concerning the availability of ANSI Z88.2-1969 and the maintenance of an historic file in connection therewith. The address of the American National Standards Institute is given in § 1910.100.

(c) No employee shall be assigned to tasks requiring the use of respirators if, based upon his most recent examination, an examining physician determines that the employee will be unable to function normally wearing a respirator, or that

the safety or health of the employee or other employees will be impaired by his use of a respirator. Such employee shall be rotated to another job or given the opportunity to transfer to a different position whose duties he is able to perform with the same employer, in the same geographical area and with the same seniority, status, and rate of pay he had just prior to such transfer, if such a different position is available.

(3) *Special clothing:* The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves, and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section.

(4) *Change rooms:* (i) At any fixed place of employment exposed to airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, the employer shall provide change rooms for employees working regularly at the place.

(ii) *Clothes lockers:* The employer shall provide two separate lockers or containers for each employee, so separated or isolated as to prevent contamination of the employee's street clothes from his work clothes.

(iii) *Laundrying:* (a) Laundrying of asbestos contaminated clothing shall be done so as to prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(b) Any employer who gives asbestos-contaminated clothing to another person for laundering shall inform such person of the requirement in (a) of this subdivision to effectively prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(c) Contaminated clothing shall be transported in sealed impermeable bags, or other closed, impermeable containers, and labeled in accordance with paragraph (g) of this section.

(e) *Method of measurement.* All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400-450 X (magnification) (4 millimeter objective) with phase contrast illumination.

(f) *Monitoring—(1) Initial determinations.* Within 6 months of the publication of this section, every employer shall cause every place of employment where asbestos fibers are released to be monitored in such a way as to determine whether every employee's exposure to asbestos fibers is below the limits prescribed in paragraph (b) of this section. If the limits are exceeded, the employer shall immediately undertake a compliance program in accordance with paragraph (c) of this section.

(2) *Personal monitoring—(1) Samples* shall be collected from within the breathing zone of the employees, on membrane filters of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) *Sampling frequency and patterns.* After the initial determinations required by subparagraph (1) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of employees. In no case shall the sampling be done at intervals greater than 6 months for employees whose exposure to asbestos may reasonably be foreseen to exceed the limits prescribed by paragraph (b) of this section.

(3) *Environmental monitoring—(1) samples* shall be collected from areas of a work environment which are representative of the airborne concentrations of asbestos fibers which may reach the breathing zone of employees. Samples shall be collected on a membrane filter of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) *Sampling frequency and patterns.* After the initial determinations required by subparagraph (1) of this paragraph, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of the employees. In no case shall sampling be at intervals greater than 6 months for employees whose exposures to asbestos may reasonably be foreseen to exceed the exposure limits prescribed in paragraph (b) of this section.

(4) *Employee observation of monitoring.* Affected employees, or their representatives, shall be given a reasonable opportunity to observe any monitoring required by this paragraph and shall have access to the records thereof.

(g) *Caution signs and labels.* (1) *Caution signs.* (i) *Posting.* Caution signs shall be provided and displayed at each location where airborne concentrations of asbestos fibers may be in excess of the exposure limits prescribed in paragraph (b) of this section. Signs shall be posted at such a distance from such a location so that an employee may read the signs and take necessary protective steps before entering the area marked by the signs. Signs shall be posted at all approaches to areas containing excessive concentrations of airborne asbestos fibers.

(ii) *Sign specifications.* The warning signs required by subdivision (i) of this subparagraph shall conform to the requirements of 20" x 14" vertical format signs specified in § 1910.145(d)(4), and to this subdivision. The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at least equal to that specified in this subdivision.

Legend	Notation
Asbestos	1" Sans Serif, Gothic or Block
Dust Hazard	¾" Sans Serif, Gothic or Block
Avoid Breathing Dust....	¾" Gothic
Wear Assigned Protective Equipment.	¾" Gothic
Do Not Remain In Area Unless Your Work Requires It.	¾" Gothic

Legend
Breathing Asbestos Dust 14 point Gothic.
May Be Hazardous To Your Health.

Spacing between lines shall be at least equal to the height of the upper of any two lines.

(2) **Caution labels**—(1) **Labeling.** Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris, and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.

(11) **Label specifications.** The caution labels required by subdivision (1) of this subparagraph shall be printed in letters of sufficient size and contrast as to be readily visible and legible. The label shall state:

CAUTION
Contains Asbestos Fibers
Avoid Creating Dust
Breathing Asbestos Dust May Cause
Serious Bodily Harm

(b) **Housekeeping**—(1) **Cleaning.** All external surfaces in any place of employment shall be maintained free of accumulations of asbestos fibers if, with their dispersion, there would be an excessive concentration.

(2) **Waste disposal.** Asbestos waste, scrap, debris, bags, containers, equipment, and asbestos-contaminated clothing, consigned for disposal, which may produce in any reasonably foreseeable use, handling, storage, processing, disposal, or transportation airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section shall be collected and disposed of in sealed impermeable bags, or other closed, impermeable containers.

(1) **Recordkeeping**—(1) **Exposure records.** Every employer shall maintain records of any personal or environmental monitoring required by this section. Records shall be maintained for a period of at least 20 years and shall be made available upon request to the Assistant Secretary of Labor for Occupational Safety and Health, the Director of the National Institute for Occupational Safety and Health, and to authorized representatives of either.

[1910.1001(b)(1) amended at 41 FR 11505, March 19, 1976]

(2) **Employee access.** Every employee and former employee shall have reasonable access to any record required to be maintained by subparagraph (1) of this paragraph, which indicates the employee's own exposure to asbestos fibers.

(3) **Employee notification.** Any employee found to have been exposed at any time to airborne concentrations of asbestos fibers in excess of the limits prescribed in paragraph (b) of this section shall be notified in writing of the exposure as soon as practicable but not later than 5 days of the finding. The employee shall also be timely notified of the corrective action being taken.

(1) **Medical examinations**—(1) **General.** The employer shall provide or make available at his cost, medical examinations relative to exposure to asbestos required by this paragraph.

(2) **Preplacement.** The employer shall provide or make available to each of his employees, within 30 calendar days following his first employment in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination, which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV_{1.0}).

(3) **Annual examinations.** On or before January 31, 1973, and at least annually thereafter, every employer shall provide, or make available, comprehensive medical examinations to each of his employees engaged in occupations exposed to airborne concentrations of asbestos fibers. Such annual examination shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV_{1.0}).

(4) **Termination of employment.** The employer shall provide, or make available, within 30 calendar days before or after the termination of employment of any employee engaged in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV_{1.0}).

(5) **Recent examinations.** No medical examination is required of any employee, if adequate records show that the employee has been examined in accordance with this paragraph within the past 1-year period.

(6) **Medical records**—(1) **Maintenance.** Employers of employees examined pursuant to this paragraph shall cause to be maintained complete and accurate records of all such medical examinations. Records shall be retained by employers for at least 20 years.

(11) **Access.** The contents of the records of the medical examinations required by this paragraph shall be made available, for inspection and copying, to the Assistant Secretary of Labor for Occupational Safety and Health, the Director of NIOSH, to authorized physicians and medical consultants of either of them, and, upon the request of an employee or former employee, to his physician. Any physician who conducts a medical examination required by this paragraph shall furnish to the employer of the examined employee all the information specifically required by this paragraph, and any other medical in-

formation related to occupational exposure to asbestos fibers.

[Sec. 1910.93a added at 36 FR 23207, December 7, 1971, as emergency temporary standard, issued as permanent standard at 37 FR 11318, June 7, 1972, effective July 7, 1972, redesignated Sec. 1910.1001 at 40 FR 23072, May 28, 1975]

§ 1910.1002 Coal tar pitch volatiles; interpretation of term.

As used in Sec. 1910.1000 (Table Z-1), coal tar pitch volatiles include the fused polycyclic hydrocarbons which volatilize from the distillation residues of coal, petroleum, wood, and other organic matter.

[37 FR 24749 Effective November 21, 1972]

§ 1910.1003 4-Nitrophenyl.

(a) **Scope and application.** (1) This section applies to any area in which 4-Nitrophenyl. Chemical Abstracts Service Registry Number 92933 is manufactured, processed, repackaged, released, handled, or stored, but shall not apply to transshipment in sealed containers, except for the labeling requirements under paragraphs (e) (2), (3), and (4) of this section.

(2) This section shall not apply to solid or liquid mixtures containing less than 0.1 percent by weight or volume of 4-Nitrophenyl.

(b) **Definitions.** For the purposes of this section: (1) "Absolute filter" is one capable of retaining 99.97 percent of a mono disperse aerosol of 0.3 µm particles.

(2) "Authorized employee" means an employee whose duties require him to be in the regulated area and who has been specifically assigned by the employer.

(3) "Clean change room" means a room where employees put on clean clothing and/or protective equipment in an environment free of 4-Nitrophenyl. The clean change room shall be contiguous to and have an entry from a shower room, when the shower room facilities are otherwise required in this section.

(4) "Closed system" means an operation involving 4-Nitrophenyl where containment prevents the release of 4-Nitrophenyl into regulated areas, non-regulated areas, or the external environment.

(5) "Decontamination" means the inactivation of 4-Nitrophenyl or its safe disposal.

(6) "Director" means the Director, National Institute for Occupational Safety and Health, or any person directed by him or the Secretary of Health, Education, and Welfare to act for the Director.

(7) "Disposal" means the safe removal of 4-Nitrophenyl from the work environment.

(8) "Emergency" means an unforeseen circumstance or set of circumstances resulting in the release of 4-Nitrophenyl which may result in exposure to or contact with 4-Nitrophenyl.

(9) "External environment" means any environment external to regulated and nonregulated areas.

(10) "Isolated system" means a fully enclosed structure other than the vessel of containment of 4-Nitrophenyl.

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FROM: J. R. MARTIN
Ext. 44825 Consultant
N-12452 Occupational Health
Safety & Fire Protection Division
Employee Relations Dept.

Date 9/11/77

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TO:

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*Please discuss w/
T J Nelson and
comment to
me.*

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